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Abstract

We apply a formal theoretical model of adaptation to two empirical settings within the agri-food industry: specialized pig production and food safety in Denmark. The objective is to allocate decision rights ex ante so that actual decisions taken ex post will optimize the profit accruing to the two parties in a contractual or integrative relation.

Two applications are presented in this paper: First an actual partnership between two pork producers in Denmark. Based on detailed budgets we develop detailed schedules for the “reneging temptations” of the two partners. These are the temptations to renege on the contract during the evolution of the partnership. Using a model developed by Baker, Gibbons and Murphy (2006) we calculate equilibria using the Folk theorem in order to determine which is the best allocation of decision rights. We find that the existing allocation of decision rights in the case we examine is efficient in the sense that it results into a second best allocation.

Using the same modelling approach we present a second application on salmonella control related to end-feeding, that is, salmonella contamination of pork due to filled bellies of pigs fed for the last 12 hours before delivery. Based on appropriate assumptions, the parties should give the decision right (whether to end-feed or not) to the slaughterhouse in order to reach the first-best solution which, given the assumptions, is feasible

JEL classifications: D21; L2; Q1

Keywords: *Theory of the firm, Adaptation theory, Contracts, Decision Rights, Pig production, Food safety*

1. Introduction

Transfer of the ownership of an asset is only one way for a firm or any agent to acquire control. It is very common among firms that decision rights are transferred without exchange of ownership of an asset. There exist ample examples in the economics literature (Lerner and Merges, 1998; Arruñada, et.al., 2001; Elfenbein and Lerner, 2003). These are usually referred to as “relational contracts”, and the business forms are usually referred to as “alliances”, “hybrids”, or “networks”. Common among these is the fact that although decisions cross firm borders, asset ownership does not always follow.

The model of Grossman and Hart (1986) (henceforth G & H); Hart and Moore (1990); and Hart (1996) has been the pioneering work in modelling “incomplete contracts” where decision rights are distinguished from asset ownership. In the G & H model, contracts are incomplete ex-ante. However, once the state is realized decisions are contractible ex-post. The parties negotiate the decision to be taken by the party with the decision right, and also negotiate a side payment to the decision maker. What drives the results of the model is the fact that the allocation of decision rights affects the size of the side payment which affects the parties’ incentives to make specific

investments ex-ante. The question raised here is: “are all decisions contractible ex-post?” Gibbons (2005), and Baker, Gibbons and Murphy (2006) (henceforth BGM) offer an alternative view: Decision rights are contractible ex-ante, but actual decisions are not contractible neither ex-ante nor ex-post.

In the BGM model, the parties negotiate over decision rights ex-ante. The challenge is to allocate the decision rights ex-ante such that optimal decisions are taken ex-post. The first such model was introduced by Simon (1951), and was recently developed further by BGM. They term this a model of “adaptation”. Spot adaptation, where parties take self-interested spot decisions is examined as well as “relational” adaptation, where parties consider their reputation in repeated interactions.

We present here two applications of the adaptation model. One refers to a partnership between two pork producers and the other on food safety on pork. Both cases are from the Danish pork industry. The theoretical model has been presented earlier (Karantininis, 2006) and will not be repeated here.

In Section 2 below the background information for both cases is presented. Sections 3 and 4 a real life example is described and in section 4 the preliminary BGM - model is introduced. The model is applied to the example on specialized pig production in chapter 5. Conclusion and discussions are in chapter 6.

The N & J pork partnership¹

Five years ago (2002), N, who is a former producer of milk and veal, started up pig production as a finisher in a partnership with J, who is producing piglets. N’s motivation for this change (after being a farmer for more than 20 years) was many years with an unsatisfying income and too many working hours.

The goals for his future life as a farmer were more time to spend with the family, time to spend on other interests and finally an improved turnover. An improved turnover would require that the production rights offered by the owned farm land were exploited in a beneficial manner. Out of these reasons pig production became his choice. However, having no skills in producing pigs in advance he decided to form a joint production company with J.

Further, from N’s perspective the main idea behind forming a joint production company had two primary purposes: First, N saw an opportunity to benefit from J being a skilled and experienced farm manager and pig producer. Secondly, N considered that it would be beneficial to focus on how to avoid or minimize the usual contractual discussions on issues like the delivered quality; prices; terms of termination and the risk of opportunistic behaviour. From his perspective time consuming and useless discussions. By involving J and choosing a partnership-model with a joint company he feels like, he has reached the goals.

1. Information on the case is kindly provided by the anonymous farmer N through interviews, accounting data, budgets and contractual agreements. Further, detailed questions on the construction of the partnership and the payment-model have also kindly been answered by the economic consultant of the partnership. Accounting data, budgets and written contracts will be made available on request. More details can be found in Graversen Karantininis, 2007.

Organization, decision rights and payments

The partnership is solely a production company and doesn't owe physical assets such as farm land, houses and other required facilities. The joint company rent the house from N and buys piglets at weaning from J.

N is the one who took on the investment of the necessary facilities (house, equipment and manure storage), and J is the manager that have the full day to day (operational) decision rights. The partnership is formally established as a so called I/S, which in the Danish legislation isn't considered as an independent legal unit, but a construction between two or more partners based on a specific contractual setup. This construction implies that income-taxes aren't paid by the company but personally by each partner according to their share of the profit.

N & J have set up a few basic principles for handling the economy and how large share of the income that should accrue to each. The first level of these principles is that only estimated costs prices of the input provided to the partnership is covered.

N is providing all the production facilities, and he is paid a rent similar to the mortgage payments on a loan at the size of the undertaken investment (variable interest rate, duration 1 year). The rent is adjusted every year in December, according to the interest rate for the coming year as set by the market for bonds. How N is really having the investment financed doesn't affect the rent.

J is providing both weaners and labour need in the production. The pigs are paid according to the costs of producing weaners as calculated in the formula prize. The price isn't affected by variations in pork prices, but is only changed when the adjusted formula prize is published every year in June and December. Provided labour is paid per hour (hours are in fact not registered but following the budgeted workload and an agreed prize per hour for the coming year).

Besides these physical inputs, N is providing the needed production rights and J is providing the management. None of these inputs are paid directly, but only by their shares of the profit in the partnership, which is divided equally between N & J when all other production costs are covered.

The future

Both N & J are satisfied with the way things are right now. At the same time they are both ambitious farmers constantly having new plans of how to develop and expand business. Since the start 5 years ago the production within the partnership is more than doubled. At the last expand, N had budgets made not only for the new investments and continued partnership, but also a budget that showed how he would manage, if he left the partnership and continued on his own. With identical efficiency levels in the two budgets they showed that he would do better on his own, as he should no longer share the profit with J.

N was, however, aware that this also meant that he himself should be the manager, or he should hire a skilled, qualified manager. Being satisfied so far with the job done by Jens, N decided to continue with the partnership. On the other hand these considerations started a process in which they (particularly N) wanted to find out if the organizational design could or should be different in order to continue cooperation where neither N nor J is being cheated – especially when the business continues to grow.

In the following, we envisage the described example with N and J in a relational contracting framework¹, and we follow Gibbons, (2005); BGM (2002; 2006); MacLeod and Malcomson (1989); Levin (2003), and Karantininis (2007).

Decision rights vs. actual decisions

In real life and the provided example the first step and question will be to identify which kind of decisions could be taken ex post that will affect the outcome of the partnership and hereby the return to N and J. Given the basic set up of the partnership we can intuitively think of several issues of relevance:

Daily management: The management will naturally affect the turnover of the partnership. For the benefit of the partnership; J, as the most skilled pig farm manager, is holding all managing decision rights in the production on a daily basis. This makes sense and since he is only paid for his effort by his share of the profit, we can not think of a situation, in which he wouldn't do the best to take actual decisions focusing an improved turnover of the partnership.

Quality: The partnership is buying all the weaners from J at a fixed price with no respect to weight, healthiness or quality in general. Adjustment of the payment (bonus or the opposite) to J for high respectively low quality is given only through the performance of the finishing represented as his share of the profit. Given the fact that J is also selling weaners and piglets to others it might be an opportunity for him to choose whether he would send highest quality² to the partnership or outside to others. As it is now, J is holding the decision right on where to send different qualities and depending on the level of the market prices on piglets there is no guaranty that he will always take decisions that are to the benefit of the partnership.

Labour: Is hired per hour from J. Based on the actual figures from the accounting it seems like an excellent deal to the partnership. The labour costs are extremely low compared to average and also compared to budgeting figures if N should be on his own and hire sufficiently skilled fulltime labour instead. On the other hand decisions on the needed labour are taken by J alone. Hereby J is having an opportunity to cheat by transferring labour costs to the partnership.

Termination: Both N and J do have the right to decide whether they want to join the partnership or not. The result to each partner is nevertheless quite different. If the partnership is terminated N will still have the opportunity to continue finishing as the facilities are own by him. Whereas J on the other hand will be out off the finishing business and only be selling weaned piglets to other finishers or to N.

The allocation of decision rights is the key focus, and we follow the simplest setting of the adaptation model as presented in chapter 4. We have a single decision right that in principle can be assigned to either of the two parties, N or J. Out of the above discussed decision issues, we find that the quality and labour are of most interest to the discussion of allocation of decision rights, since actual decisions taken here can affect payoffs from the partnership significantly.

1. In this chapter the N and J notation will only be used as illustration and to support discussion. The model will be kept at a generic level. In chapter 5 the model is applied to the case using budget and accounting data from the partnership

2. Quality levels in piglets would regard issues such as weight, health, weight variations in each batch etc. Elements that would affect the performance of the finishing.

The question of termination is in fact already a part of the analysis. Throughout the analysis we ask if the present value of the benefits created by d^{RC} outweighs the benefits from the self-interested decision, d^{SP} , given that ongoing self-interested decisions means that the other party eventually will stop cooperation.

When turning the setting down to only a single decision right in the step of the analysis, we can also leave the labor question out due to a couple of reasons. The parties are both aware of J having the opportunity to cheat on labor. So in order to deal with this, J presents a budget on labor every year to be approved by N. In the following year; J is then only being paid what is agreed according to the budget.

The unsolved question on quality seems to be more complex, and it hasn't been dealt with in the contract by N and J. In our case; allocation of the right to decide, whether the input should be the (potentially) high or low performance group, is only contractible and possible to give to both parties if the quality level is observable to both. This might not be the case. J will assumable have better opportunities to observe actual quality and hereby also what is decided to be the input to the partnership. When J holds the decision right, N will expectedly not be able to observe what is decided, but the results of the decision are observable but not verifiable.

The single decision right is then cut down to whether the quality of the piglets delivered to the partnership should be high or low. Considerations on quality can easily be rather complex, so without going in to detailed discussions of what is high and low quality weaners, we will as mentioned only consider two quality levels – high or low. Applied to the example it means that we think of J, as if he is having the opportunity to divide every single weaned batch of piglets in to two groups with different performance potential (high or low) at the stage of finishing^{1,2}

States

The parties have private (inalienable) benefits π_N and π_J , respectively, which depend on the state of nature, s . In the example the states are chosen as various price/feed ratio levels distribution (Appendix A1 presents background data including historical distribution) and the calculation of the price/feed ratios). The states are observable but not verifiable by both parties. The benefits π_i ($i=N, J$) depend also on the decision $d_i \in D$ which is chosen after the state s is revealed. The states are price/feed ratios based on used feed prices in the national formula price in years 2001-2006. Min and max ratios found are found payoffs are calculated with equal distribution between min and max.

Calculations

The calculations of the potential payoffs with indifferent setting are calculated based on the budgets and accountings from both the partnership and from the farmer N. However, we haven't had an opportunity to take a look at accountings and budgets from J. In order to deal with the missing information, we have set up budgets for all scenarios relative to the productivity and efficiency levels used when calculating the national formula price. Relative levels regarding the partnership and N's economy comes from the actual figures. In the case of J's economy the re-

1. For more background information on the economic impacts of different quality levels and what could influence the performance at finishing, see Bonefeldt & Nørgaard (1999), Graversen et al. (2002)

2.

lative levels are set as estimates according to what we now about his performance as manager in the partnership.

Regarding the quality choices the basic assumption are; if J transfer piglets of lower quality to the partnership; especially variable (feed) costs will increase within the partnership. This can only be to the interest of J, if dividing the weaners into two groups will result in a higher price when the highest quality groups are sold to others. The lower performance results in declining profit in the partnership – a loss of which half is N's. In the calculations it is assumed that a high quality bonus of 5-10 DKK pr. weaner can be gained, and weaners of lower quality will result in a 5 percent increase of variable costs at finishing in the partnership.

According to assumptions made payoffs are calculated in the following scenarios:

- Total profit per finished pig accruing to N if he is:
 - S1. Joining the partnership and J has decided to transfer lowest quality to the partnership and sell highest quality to others
 - S2. Joining the partnership and J has decided to transfer highest quality to the partnership and sell lowest quality to others
 - S3. Doing the finishing himself. Hiring skilled labour and buying the weaners at the formula price.
- Total profit per produced weaner and/or finished pig accruing to J if he is:
 - S4. Joining the partnership and he has decided to transfer lowest quality to the partnership and sell highest quality to others
 - S5. Joining the partnership and he has decided to transfer highest quality to the partnership and sell lowest quality to others
 - S6. Selling all the weaners to others and not being involved in finishing at all.

A situation in which N is given the decision right to choose the quality level of the weaners is not carried out separately. Intuitively, he will always choose the high quality input (Figure 1); accordingly this scenario is similar to the one where J decide to sell lowest quality to others. In Figure 1 are the payoff to N if he is joining the partnership (scenario 1 and 2) and if his being on his own (scenario 3).

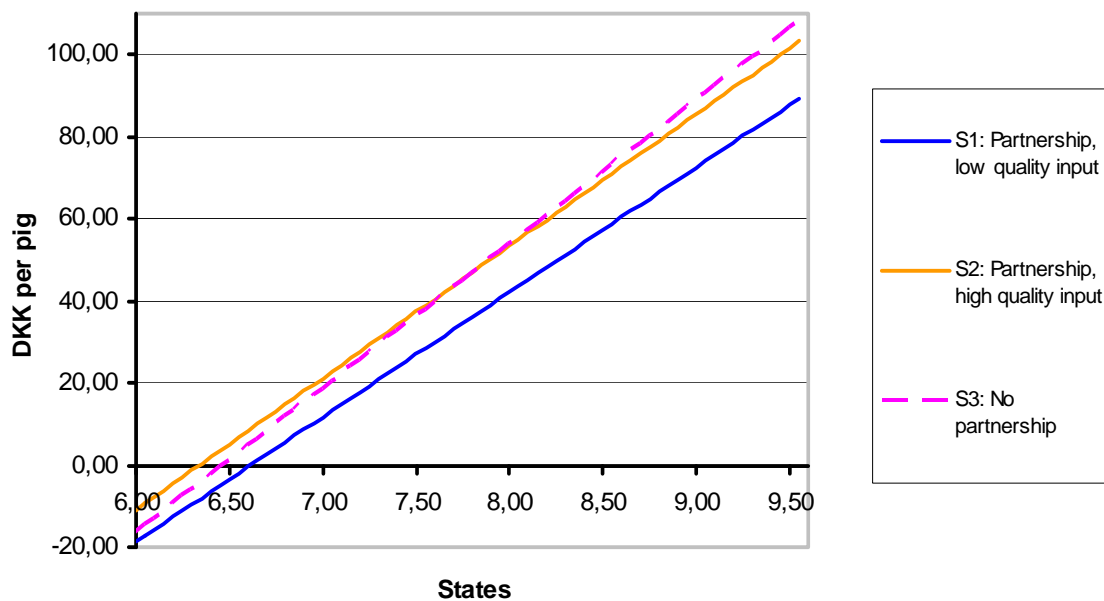


Figure 1. Profit to N in scenario 1, 2 and 3

Similarly, in Figure 2 are the net benefits to N if he is joining the partnership (scenario 1 and 2) instead of being on his own (scenario 3).

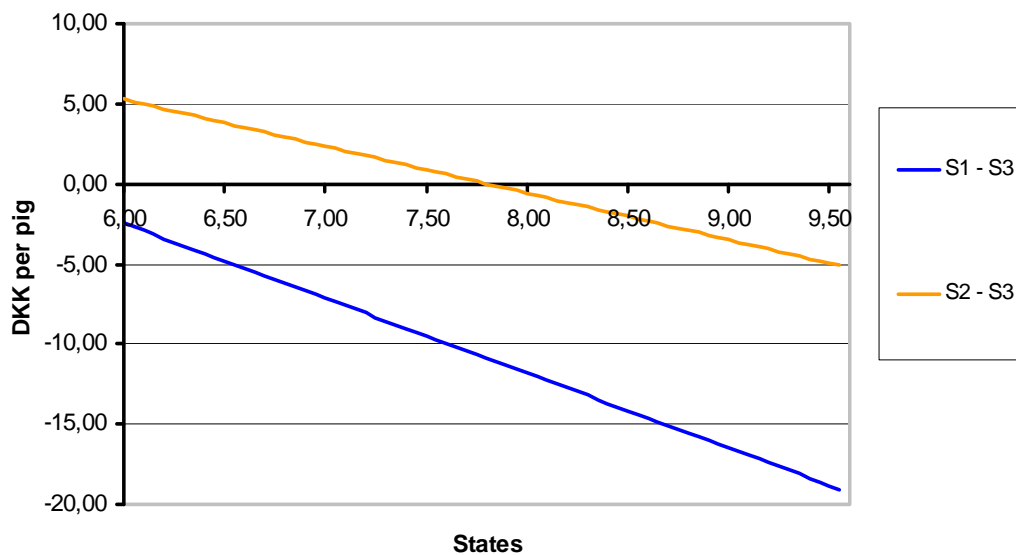


Figure 2 . Net benefits to N if joining the partnership

From Figure 2 it is obvious that N will not always benefit from joining the partnership. In bad times (low ratios) and high quality input he will profit from joining the partnership, whereas in good times (high ratios) he will not. On the other hand, if the delivered weaners are from the lower performing group, he will never benefit from joining the partnership. Further from Figure 2, we see a clear explanation of why N is asking whether it's profitable for him to continue the

partnership or not. Depending on the actual decisions taken by J regarding quality, it certainly has its price to N being cooperative as to day. The higher the ratios are, the more will N be tempted to bring the partnership to an end.

The situation to J is somewhat different, as he will not be in finishing, if he isn't joining the partnership¹. The question for him is therefore a matter of finding out if it is beneficial to take part of the finishing or if it is better only to sell weaners and piglets. In Figure 3 are payoffs to J if he is joining the partnership (scenario 4 and 5) and if his selling all weaners and piglets to others and not joining the partnership (scenario 6).

In Figure 4 are the net benefits to J if he is joining the partnership (scenario 4 and 5) instead of being on his own (scenario 6). Except from periods with very low ratios J will always benefit from joining the partnership no matter the decision taken regarding quality.

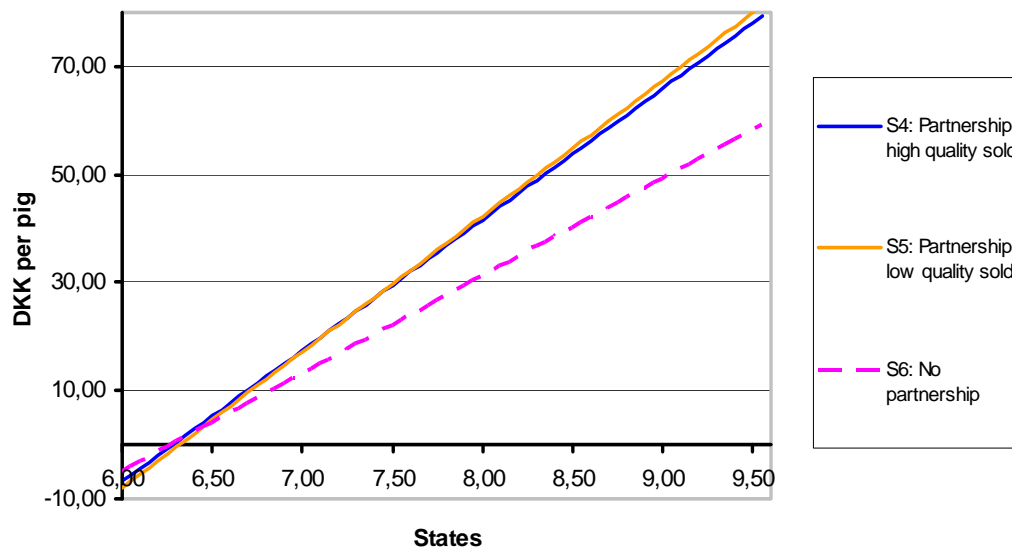


Figure 3. Profit to J in scenario 4, 5 and 6

1. If he finds another "partnership-partner" or invest in finishing himself, then he will still be in business, but it will not be his immediate alternative.

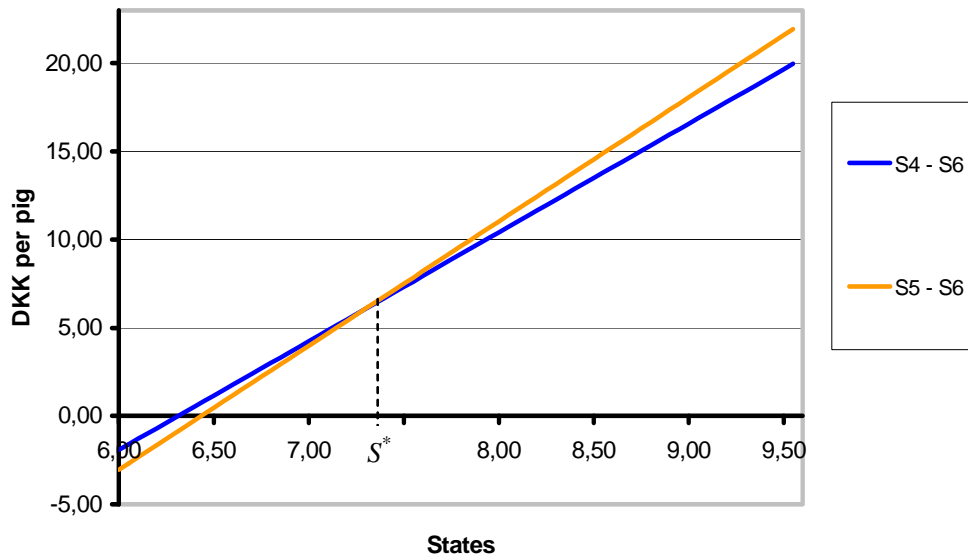


Figure 4. Net benefits to J if joining the partnership

In states with ratios below S^* he will be able to gain a minor profit if selling the high quality group to others and transfer the rest to the partnership. In this period he will be tempted to take a self- interested decision. In good times (ratios above S^*) he will without any questions only transfer weaners of the highest quality to the partnership.

Conclusion and discussion on the N & J case

Relational contract: N & J:

- Enforced by the parties out of concern for their reputations
- “The relational part” is unwritten and can not be enforced by court
- Rely instead on parties calculation of the long-term benefits of cooperation versus the short term self-interested benefits of cheating or defection

Further, from N’s perspective the main idea behind forming a joint production company had two primary purposes: First, N saw an opportunity to benefit from J being a skilled and experienced farm manager and pig producer. Secondly, N considered that it would be beneficial to focus on how to avoid or minimize the usual contractual discussions on issues like the delivered quality; prices; terms of termination and the risk of opportunistic behaviour. From his perspective time consuming and useless discussions. By involving J and choosing a partnership-model with a joint company he feels like, he has reached the goals.

3. The Salmonella case in Danish pork

A number of measures have proved to be effective on reducing the salmonella level on Danish pork, both at the farm and at the abattoir levels. At the farm, some measures relate to external suppliers. For example, salmonella in breeding animals from other farms and salmonella in feed from feed mills have been a major source of infection of the herds (Coma, 2003). Among the management measures are rodent control, limited commingling of piglets and change of clothes

and equipment between the building sections. In addition, pig producers must implement thorough cleaning and disinfection procedures (European Commission, 2003).

At the abattoir level certain measures can be used to prevent contamination of the carcasses. As described above, salmonella is only found in the intestine, belly and mouth. Therefore the crucial point emerges when the guts are removed from the carcass and the carcass is split into halves. If the belly breaks and leaks, there is a serious risk of contamination of the carcass. To avoid this from happening it is important that the pigs have empty bellies at the time of delivery. Therefore the pigs should not be fed for the last 12 hours before delivery to the slaughterhouse. Among other measures is hot-water decontamination of all equipment at the slaughterhouse. Pigs from herds with salmonella level 2 and 3 (according to the ranking system described below) are furthermore subject to sanitary slaughter, where the pigs are slaughtered at the end of the day under an increased sanitary level (FVST, 2006).

Penalties and incentives

As a part of the salmonella control program, the Danish food safety authorities have implemented monitoring procedures, both at the farm level and at the slaughterhouses. The monitoring system is followed up by a financial penalty system based on the salmonella level of the pig herd. Similarly, the slaughterhouses have to initiate increased efforts against salmonella, in case there are found salmonella on carcasses in amounts larger than tolerated by the food safety authorities.

The monitoring of the farm level is actually carried out at the slaughterhouse. Depending on the number of pigs delivered, the slaughterhouse picks out meat samples from 60 to 100 pigs per year. The pigs are automatically selected at the abattoir. The meat juice from the samples is successively tested for salmonella antibodies. If the concentration of antibodies, on a scale from 1 to 200, is above 10, the sample is considered positive. When a pig is infected with salmonella it will begin producing antibodies within two to four weeks and keep producing until the infection is possibly overcome. Thus, the concentration of antibodies and the actual degree of infection are highly correlated. In addition, the test is very inexpensive.

Every month a slaughter pig index is calculated based on the percentage positive samples from the herd. The index is based on the latest 3 months (rolling) and weighted such that the latest month weighs 3 times the subsequent 2 months (Alban et al., 2002). Table 1 illustrates how the slaughter pig index is calculated.

Table 1: Slaughter pig index

Month	Pct. positive samples	weight	Weighted pct. positive samples
January	50	0.2	10.0
February	33	0.2	6.6
March	29	0.6	17.4

Slaughter pig index in April: $10.0 + 6.6 + 17.4 = 34$

The slaughter pig index is subsequently used to categorize the herd in one of 3 levels according to the salmonella prevalence. The majority of the Danish herds are categorized in level 1.

Table 2: Salmonella level

Salmonella level	Slaughter pig index
1	0 - 39
2	40 - 69
3	70 - 100

If a pig producer is categorized in level 2 or 3, she will be penalized by a deduction in the payment from the slaughterhouse. In level 2 a deduction of 2 percent is made and in level 3 the deduction is 4, 6 or 8 percent, depending on how long time the herd has been in level 3. In this way, the pig producer faces strong incentives to implement measures against salmonella, both preventive measures and, in case of a break out, measures to disinfect the herd.

The slaughterhouses are also monitored for salmonella, however, at this link of the production chain the monitoring is not based on meat juice samples. Instead the slaughterhouse has to take samples from the moisture on the chilled carcasses, thus, the samples are not tested for antibodies but for actual salmonella bacteria. Hence, the slaughterhouse is not testing for salmonella in the guts of the pig but for salmonella on Allocation of decision rights in relational contracts the meat due to contamination during the slaughter process. The slaughterhouse makes 5 samples every day which together constitutes a collective sample. If the slaughterhouse has more than one positive collective sample (only one of the individual samples needs to be positive) during 11 days, it is obliged to identify the cause of the contamination. Every month the percentage of positive collective samples over the last year is calculated. If the slaughterhouse has had more than 2.2 percent positive collective samples and if there has been 1 positive collective sample during the last month, the slaughterhouse is pointed out. If the slaughterhouse is pointed out in 4 out of 6 months, the food safety authorities call for an “increased effort”. The slaughterhouse then has to take extra samples and work out a plan on how to bring down the contamination level. After 6 months the plan is evaluated based on the development in positive samples. If the plan does not have the intended effect, the food safety authorities call for further action. The cost of taking samples, working out the plan and implementing it is solely born by the slaughterhouse (DFVF, 2004).

The Salmonella Contract

Following BGM and Karantininis (2006) we develop a model of the contractual allocation of decision rights between the Farmer and the Abattoir. The subject of the contract is whether or not the pig producer should be allowed to feed the pigs during the last 12 hours before delivery (termed an end-feeding contract in the following). The end-feeding contract, which can be written (but without being enforceable), can be seen as a subcontract or a supplementing contract, forming part of the contractual relationship between the pig producer and the slaughterhouse. In the following, it is assumed however, that the end-feeding contract does not have an effect on the rest of their contractual relationship.

If one party breaches the end-feeding contract (reneges) the consequence will be a continuing contractual relationship between the parties, but with no agreements about end-feeding, i.e., the parties will choose spot decisions over this issue. The end-feeding issue The reason why end-

feeding needs to be contracted upon is found in the conflicting interests of the pig producer and the slaughterhouse concerning this issue. The pig producer wants to feed his pigs right until the moment they are picked up for delivery to the slaughterhouse, in order to maximize the weight gain during the production period.

On the other hand, the slaughterhouse wants the bellies and intestines to be empty by the time the pigs arrive at the abattoir. This is especially important for the slaughterhouse when the pigs are infected with salmonella. The reason for this is that bellies occasionally break and leak during the process of emptying the carcass. When that happens, the carcass gets contaminated and might – even after thorough cleaning – be infected with salmonella bacteria. Therefore, the higher the salmonella level of the pig, the higher is the risk of salmonella contamination in the pork (Christensen, 2007).

The slaughterhouse is penalized by the food safety authorities as described above. Sanctions are introduced when the number of positive meat samples reaches a certain Allocation of decision rights in relational contracts level – both termed in percentage per year and in absolute numbers per month. The first step is a demand from the authorities for an “increased effort”. This initially includes a plan prepared by the slaughterhouse, which identifies initiatives to bring down the amount of salmonella contaminated pork from the slaughterhouse. If the situation does not improve, the food safety authorities will call for further efforts from the slaughterhouse. Preparing these plans and increasing the efforts of course incur additional costs to the slaughterhouse.

As described earlier, a large percentage of the Danish pork meat is exported to a large number of countries. In the majority of these countries Danish pork is chosen specifically because of the relatively high food safety level. The consequence, however, is a market which is quite sensitive to increased salmonella levels in pork (DMA, 2007). Altogether, the slaughterhouse therefore will experience both increased costs from efforts against salmonella and lower revenues due to lower demand and/or lower prices.

It is very important, therefore, for the slaughterhouse to avoid level-3-pigs with filled bellies and hence the risk of higher levels of salmonella contamination in pork. The pig producer, on the other hand, incurs no costs from the contamination of the pork meat. The salmonella level in the pig herd, and the corresponding financial penalty, is determined from the count of anti-bodies in meat-juice samples. This number only tells something about the salmonella infection in the belly and intestine of the pigs – not the salmonella transmitted to the pork meat at the slaughterhouse. Thus, the financial penalty system does not provide any incentives for the farmer to reduce the risk of contamination of the carcasses at the slaughterhouse. This problem could therefore appear to be one of mal-incentives in the farmer’s penalty system. Accordingly, the solution would be to let the farmer bear part of the financial penalty of the slaughterhouse in order to create better incentives for empty bellies when there is a high salmonella level on the farm. However, this is only an option if the food safety authorities (or the slaughterhouse, if they manage the penalty program) can observe the amount of belly content and if the amount is verifiable. That is exactly the case in the testing of meat juice samples, which constitutes the measurement in the pig producers’ current salmonella control program. Except from the indirect influence via the belly content on the contamination of the pork, the farmer has no influence on the level of contamination of pork at the slaughterhouse.

Therefore, the current control program on salmonella in pork provides incentives for the slaughterhouses, which also predominantly has the opportunity to take actions against salmonella in pork. One might instead suggest that the pig producer and the slaughterhouse could sol-

ve this problem by writing a (supplementing) contract which determines at which states the pig producer is allowed to end-feed his pigs (say, level 1) and when he – in return for a suitable side-payment – is not allowed to end-feed the pigs (level 2 and 3). The efficient contract would let the pig producer end-feed his pigs in states (salmonella levels) where the increased profit to the pig producer, due to end-feeding, is equal to or exceeds the expected decrease in profits experienced by the slaughterhouse caused by the filled bellies. In other states, where the increase in profit from end-feeding is lower than the decrease in profits from filled bellies, the pig producer should not be allowed to end-feed. Given that the Coase Theorem applied, this contract would be Pareto efficient.

For such a contract to be implementable however, the pig producer's decision (whether to end-feed or not) needs to be observable to both parties and verifiable by a third party, i.e. a court. Of course the pig producer knows whether he has end-fed the pigs or not. The slaughterhouse is also able to observe the content of the bellies and determine whether the pig producer has turned off the feed supply several hours before delivery or if he has acted less carefully and turned it off only a couple of hours before delivery.

One might also assume that it is possible for a third party to determine the decision of the pig producer with a certain probability; however, it is very realistic to assume that it is impossible to verify his exact decision without implementing a thorough monitoring system. Such a system is assumed to require huge efforts and be associated with costs out of all proportion to the profits at stake. Therefore, from an economic point of view, the decisions of the pig producer are non-verifiable.

Spot transactions

In a spot setting or the last period of a relational contract, the parties would renege and maximize their private profits at the current moment. For the pig producer this means end-feeding of the pigs without considering the salmonella level and for the slaughterhouse it means not paying bonus whether the bellies are empty or not. This would happen because neither the pig producer nor the slaughterhouse would have the opportunity to punish the other party for renegeing, in the future. As a result, the parties can “defect” on the contract and walk away with higher profits. Note that this is a different setup compared to the existing contract on control of salmonella at the farm. In this contract the efforts are indirectly verified via the count of salmonella anti-bodies in meat-juice and penalties are given accordingly. This is only possible because the decisions of the pig producer are indirectly verifiable.

Relational contracting

In a relational contract setting, no contract can be enforced. Instead the parties will consider the future benefits from their cooperation and consider the discounted value of the end-feeding contract (the bonus for not end-feeding to the farmer and the empty bellies to the slaughterhouse) and compare it to the profit of the spot decision. In this way, the pig producer and the slaughterhouse might be able to generate a higher total profit from their cooperation than under spot governance. However, the relational contract will only be sustained as long as neither of the two parties renege and choose the spot decision. The temptation to renege is determined on basis of several factors. One of these factors is the expected length of their future cooperation; the longer the pig producer and the slaughterhouse expect to cooperate (transact with each other) the higher the discounted value of future profits and hence the lower the temptation to renege. It works the opposite way in relation to the profit from the spot decision; the higher spot profits foregone

by not choosing the spot decision, the bigger the temptation to renege. Finally, the discount rate influences the reneging temptation; the higher discount rate, the lower present value of future profits from relational decisions and hence the higher temptation to renege.

It follows from the theoretical model (Karantininis, 2007), that the highest possible net surplus is reached by giving the decision right to the party with the lowest maximum reneging temptation.

The model

In general this model builds on the theoretical model and the relationship between the pig producer and the slaughterhouse as described above. In addition the model incorporates the following specific assumptions:

Decision rights There exists one decision right; namely whether the pig producer may or may not endfeed. The decision right can be held by either the pig producer or the slaughterhouse.

States

The pig producer and the slaughterhouse are assumed to observe three possible states formed by the three possible salmonella levels of the pig producer's herd:

S1 = Salmonella level 1

S2 = Salmonella level 2

S3 = Salmonella level 3

The states are verifiable, as the Danish food safety authorities collect and analyze samples of meat-juice to determine the salmonella level. The results are successively shared with both the pig producer and the slaughterhouse. The states (and the underlying antibody count within the states) are furthermore assumed to be uniformly distributed.

Timing of the model

1. Decision rights are allocated.
2. The first payment might be an "efficiency wage" paid from the slaughterhouse to the pig producer or vice versa before the state or any decisions are observed
3. Salmonella level 1, 2 or 3 is revealed.
4. Post-state "bribe" is paid.
5. The decision to (allow for) end-feed or not is taken by the party that holds the decision rights.
6. Finally a bonus might be paid.
7. The profits for the slaughterhouse and the pig producer are realised.

Payoffs to the pig producer

The calculated payoffs for the pig producer are primarily based on the annual analysis of the productivity and economic results of Danish pig production (2006) (Produktionsøkonomi 2006, swin) published by the Danish Agricultural Advisory Service (Dansk Landbrugsrådgivning, Landscentret, 2007). The numbers are summarized in Table 3 below.

Table 3

Pig producer: Salmonella level 1:	
Average daily weight gain (kg)*	0,849
Assumed daily weight gain at end of production period (kg)	1,200
Feed Units per kg pig produced (FU)*	2,8
Cost per Feed Unit (DKK)*	1,18
Cost per kg pig produced (DKK)	3,30
Revenue per kg pork-meat (carcass)* (DKK)	9,64
Meat-percentage in slaughtered pig* (%)	60,2%
Revenue per kg pig produced* (DKK)	5,80
Pig producer's marginal profit from end-feeding per day (DKK)	3,00
Profit from end-feeding for 12 hours, salmonella level 1	1,50
Pig producer: Salmonella level 2:	
Assumed daily weight gain at end of production period (kg) (level 1 - 5%)	1,140
Profit from end-feeding for 12 hours, salmonella level 2	1,42
Pig producer: Salmonella level 3:	
Assumed daily weight gain at end of production period (kg) (level 1 - 10%)	1,080
Profit from end-feeding for 12 hours, salmonella level 3	1,35

*Source: Dansk Landbrugsrådgivning, Landscentret (2006)

The average daily weight gain of a slaughter-pig has been 849 grams on average in year 2005. We furthermore assumed the daily weight gain by the time of delivery to be 1200 grams for pigs in salmonella level 1. This is a reasonable assumption, as the pig at that moment has gained 74 kg in total and has a body weight of about 100 kg. We also assumed that pigs categorized in level 2 and level 3 on average grow 5 percent and 10 percent less per day respectively.

The marginal cost of producing one kg (weight gain) of slaughter-pigs is assumed to be equal to the cost of the required feed. Danish pig producers used on average 2.80 Feed Units per kg pig produced in 2005. The cost was 1.18 DKK per Feed Unit thus incurring a cost of 3.30 DKK per kg pig produced. The revenue from producing pork was 9.64 DKK per kg pork in 2005. With a meat percentage of 60.2 percent in slaughtered pigs, the revenue is equal to 5.80 DKK per kg pig produced. Thus, marginal profit to the farmer from end-feeding for one day is equal to 3.00 DKK. Allocation of decision rights in relational contracts to 3.00 DKK. Hence the profit from end-feeding for 12 hours is equal to 1.50 DKK for pigs in salmonella level 1. In salmonella level 2 the profit is 5 percent lower and thus equal to 1.43 DKK. Finally, in salmonella level 3 the profit is 10 percent lower and thus equal to 1.35 DKK.

Profits to the slaughterhouse

The following calculations, which are shown in Table 4, are in part based on information provided by Christensen (2007). The slaughterhouse faces two sources of increased costs from end-feeding.

Table 4

Slaughterhouse:		
Assumed cost of handling belly content, filled belly (DKK)	0,10	
Contamination ratio, belly content on meat (%)*	1,0%	
Assumed time attempt to decontam.: (5 minutes · 250 DKK per hour) (DKK)	21,00	
Assumed ave. cost from contam. with belly content, excl salm. costs (DKK)	0,21	
Total assumed cost from filled belly, excl. salmonella costs (DKK)	0,31	0,31
Assumed decontamination failure rate: (%)	10,0%	
Contaminated after cleaning = Contam. ratio · decontamination failure rate	0,1%	
Probability of salmonella in belly of salmonella-level-1-pig	16,5%	
Probability of <i>salmonella</i> contamination of carcass from salmonella-level-1-pig	0,0165%	
Assumed cost of salmonella contaminated carcass (DKK)	2500,00	
Average cost of salmonella, filled bellies, salmonella level 1 pigs (DKK)	0,41	0,41
Total expected cost from filled belly in level 1 pig (DKK)		0,72
Probability of salmonella in belly of salmonella-level-2-pig	58,50%	
Probability of <i>salmonella</i> contamination of carcass from salmonella-level-2-pig	0,0585%	
Assumed cost of salmonella contaminated carcass (DKK)	2500,00	
Average cost of salmonella, filled bellies, salmonella level 2 pigs (DKK)	1,46	1,46
Total expected cost from filled belly in level 2 pig (DKK)		1,77
Probability of salmonella in belly of salmonella-level-3-pig	87,5%	
Probability of <i>salmonella</i> contamination of carcass from salmonella-level-3-pig	0,0875%	
Assumed cost of salmonella contaminated carcass (DKK)	2500,00	
Average cost of salmonella, filled bellies, salmonella level 3 pigs (DKK)	2,19	2,19
Total expected cost from filled belly in level 3 pig (DKK)		2,50

*Source: Christensen (2007)

Firstly, the slaughterhouse incurs an increased cost from handling the content of the belly and intestine, including the cost of cleaning when the belly breaks and leaks. This cost is independent of the salmonella level of the pigs. The cost of handling bellies which do not break is assumed to be 0.10 DKK per pig. Furthermore it is assumed, that the number of bellies which break is equal to 1 percent. The cost of cleaning the contaminated carcass is assumed to be 21 DKK resulting in an average cost of 0.21 DKK per end-fed pig.

Altogether, the costs of end-feeding, excluding costs of salmonella contamination, sum up to 0.31 DKK per pig. Secondly, the slaughterhouse incurs a cost from the salmonella contamination of the carcasses. This cost is depending on the salmonella level of the pigs. Initially we calculate the probability of contamination (with or without salmonella) after cleaning of the carcass. That is equal to 1 percent contaminated carcasses times an assumed decontamination failure rate of 10 percent, resulting in 0.1 percent contaminated carcasses after cleaning. The number of salmonella contaminated carcasses then depends on the probability of salmonella bacteria in the belly of the contaminated pigs. In other words, the salmonella level of the pigs become important at this stage.

In Table 5 we have calculated the expected percentage of salmonella infected pigs in each salmonella level. It is a quite simple calculation based on the assumption that the probability of salmonella infection in a pig from a herd which is categorized in, say, salmonella level 1, is equal to the average infection of the worst case scenario and the best case scenario in salmonella level 1 herds. We thereby assume that the distribution within each salmonella level is uniform, i.e., that the average level 1 herd has a salmonella index of 19,5. we also assume that, among the many possible combinations of positive monthly meat-juice samples within each salmonella level, the average number is equal to the average of the worst case scenario and the best case scenario. Allocation of decision rights in relational contracts

Table 5

Salmonella level 1:			
Worst case scenario:	% pos	weights	
January:	0	0,2	0
February	0	0,2	0
March	33	0,6	19,8
Salmonella index			19,8
Best case scenario:			
January:	100	0,2	20
February	0	0,2	0
March	0	0,6	0
Salmonella index			20
Average % pos. samples in March	16,5		
Salmonella level 2:			
Worst case scenario:	% pos	weights	
January:	0	0,2	0
February	0	0,2	0
March	92	0,6	55,2
Salmonella index			55,2
Best case scenario:			
January:	100	0,2	20
February	100	0,2	20
March	25	0,6	15
Salmonella index			55
Average % pos. samples in March	58,5		
Salmonella level 3:			
Worst case scenario:	% pos	weights	
January:	25	0,2	5
February	100	0,2	20
March	100	0,6	60
Salmonella index			85
Best case scenario:			
January:	100	0,2	20
February	100	0,2	20
March	75	0,6	45
Salmonella index			85
Average % pos. samples in March	87,5		

Following the calculation of expected percentage of salmonella infected pigs we have calculated the expected percentage of salmonella contaminated carcasses in each salmonella level. This number, together with the expected marginal cost to the slaughterhouse of salmonella infected carcasses (the cost of one additional salmonella contaminated carcass), makes me able to calculate the expected cost to the slaughterhouse of end-fed pigs in each salmonella level.

Finally, we add together the general costs from end-feeding and the salmonella specific costs from end-feeding and thus calculate the expected cost per pig from filled bellies. Now we have calculated both the profit to the pig producer and the cost to the slaughterhouse from end-feeding in the 3 salmonella levels. Before turning to the results it would be appropriate to explain some of the other important assumptions in the calculations above. As shown in table 4, we have assumed the marginal cost to the slaughterhouse from salmonella contaminated carcasses to be 2500 DKK. To be honest, that number is only an estimate of the marginal costs. Of course, the real cost need to be calculated before this model can be implemented in Danish pork production. However, as we have described above, the model for testing and penalizing the slaughterhouse is very complex, not least from a statistical point of view. In addition, the cost from lost market value of Danish pork due to increased salmonella prevalence also needs to be calculated before the total cost per end-fed pig can be determined. Therefore, we have chosen to assume a realistic cost of end-feeding and thus enable my self to reach the aim of this report, namely to develop an illustrative model and derive important results on allocation of decision rights based on the model.

At this point it is also worth noting, that the above calculated numbers are based on the implicit assumption that the pig stops growing as soon as the pig producer stops feeding it. This assumption might also be a little too simplistic for a real world model. Thus, of course the exact correlation between current feeding and current growth need to be determined. For now, we stick to this assumption in order to be able to present the results of the model.

Another assumption behind the numbers above is that salmonella, when no measures are taken, is likely to be found in the herd in a certain month, if it was found the previous Allocation of decision rights in relational contracts month. Thus, we thereby assume that salmonella does not disappear randomly but only after necessary measures are taken. Finally we also assume that salmonella prevalence is uniformly distributed within the states, i.e. level 1 pigs on average have salmonella in 19,5 percent of the samples (because level 1 herds have 0 – 39 percent positive samples). Allocation of decision rights in relational contracts.

4. Results

Spot contracting

Initially, we assume that the pig producer and the slaughterhouse on only meet and transact once, i.e., they are in a spot setting. In that case, as described above, the decision right should be given to the party who produces the highest surplus by taking her self-interested spot decision we therefore turn to calculate the expected surplus created from the self-interested decisions of the pig producer and the slaughterhouse respectively. If the pig producer is given the decision right, she will decide to end-feed no matter which salmonella level her pig herd is categorized in, because she has a positive profit from end-feeding in all levels. The expected profit can thus be calculated as

$$\Pi_F^{SP} = \frac{1.50 + 1.42 + 1.35}{3} = 1.42$$

Likewise, the expected profit of the slaughterhouse's self-interested decision can be calculated:

$$\Pi_A^{SP} = \frac{0.72 + 1.77 + 2.50}{3} = 1.66$$

Accordingly, under spot governance, the decision right should be given to the slaughterhouse, because it produces the highest expected profit. At this point it is worth noting, that the decision rule does not say anything about which party receives the profits. Hence, if the pig producer is somehow entitled to the right to end-feed, or if she possesses enough bargaining power, she will receive all the profits made from the slaughterhouse's decision and vice versa. In short, the parties will always let the party, who can generate the highest profit, decide. Then it is only a matter of distribution who will eventually receive the profits.

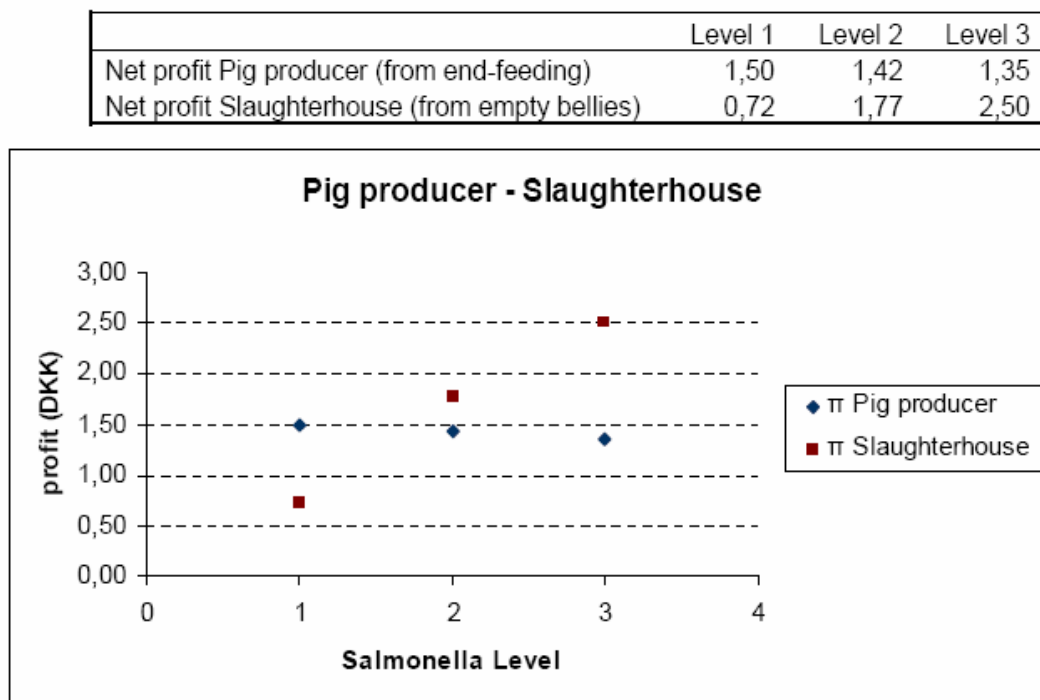


Figure 5.

In figure 5 it becomes quite clear, that letting the slaughterhouse take its self-interested decisions results in a profit loss when pig herds are categorized in salmonella level 1, where the pig producer can make an expected profit of 1.50 DKK from end-feeding, whereas the slaughterhouse only encounter an expected loss of 0.72 DKK. Thus, the parties encounter a potential net profit loss of 0.78 DKK per level 1-pig due to the spot decision of the slaughterhouse. If the parties could contract on the actual decision about end-feeding or not, they would therefore let the pig producer end-feed in salmonella level 1. However, as described above, the decision to end-

feed or not is not contractible and the parties therefore cannot contract over the actual decision to be taken in different states (levels).

Relational contracting

On the other hand, the pig producer and the slaughterhouse are, like mentioned before, under normal circumstances, not making spot transactions with each other. Instead they meet over and over again in repeated transactions. Thus, it might be possible to design a decision rule where the deciding party in some states make a decision different from her spot decision with the prospect of increasing total profits and receive an adequate amount of these profits in the future. In figure 5, it is quite easy to see that the profit maximizing decision rule would be to let the pig producer end-feed when her pig herd is in salmonella level 1 and not let her end-feed in levels 2 and 3. Under this particular decision rule the highest possible profit is made in each salmonella level. Therefore this would be a first-best decision rule. Such a decision rule might be implementable, however, we still assume that the slaughterhouse and the pig producer make self-interested decisions, and therefore such a decision rule needs to provide higher net present values at any salmonella level than the profits currently foregone by the decider if she follows the decision rule. In other words, the maximum reneging temptation, i.e., the profit from the immediate self-interested decision must never exceed the present value of the profit created by the decision rule. Otherwise the party in control will choose to renege and the slaughterhouse and the pig producer will return to the less profitable spot decision rule.

For example, assume that the parties have agreed on a relational contract constituting the first-best decision rule described above. Also, let the pig producer have the decision right. If her pig herd, at the time of a given transaction, is in level 1 she will definitely comply with the decision rule and end-feed her pigs. If instead her pig herd is in level 2 or 3, she will be committed to not end-feed according to the decision rule. However, in those salmonella levels she will forego a profit of 1.42 and 1.35 per pig by complying with the decision rule. The central question then is if the expected future profits are large enough to exceed her reneging temptation.

If the future categorization of the herd is uniformly distributed between the 3 salmonella levels and if the interest rate is assumed to be 10 percent, the present value of the expected profit from the relational contract can be calculated by discounting the difference in profits between the relational contract and the spot contract:

$$\frac{1}{0.10} \cdot \frac{(1.50 - 0.72) + (1.77 - 1.77) + (2.50 - 2.50)}{3} = \frac{1}{0.10} \cdot \frac{0.78}{3} = \frac{1}{0.10} \cdot 0.259 = 2.59$$

Hence, given an interest rate of 10 percent, the present value of the relational contract is 2.59 per pig, which by far exceeds the pig producers reneging temptation of 1.42 and 1.35 in level 2 and 3 respectively. This is shown in Figure 6.



Figure 6.(Discount rate: 10 percent).

If we then turn to the slaughterhouse, the relational contract is equal to the slaughterhouse's spot decision in levels 2 and 3, but in level 1, if the slaughterhouse holds the decision right, the slaughterhouse faces a reneging temptation equal to its spot profit in level 1. However, the present value of the relational contract also by far exceeds the slaughterhouse's reneging temptation of 0.72 per pig.

With a constant present value over the 3 salmonella levels of 2.59 of the relational contract it is relatively easy to conclude that the present value of the relational contract Allocation of decision rights in relational contracts exceeds both parties' maximum reneging temptation. However, if the discount rate is increased, the future value of the profit from the relational contract decreases and hence the relational contract might not be implementable. This is illustrated in Figure 7 where the discount rate is set at 45 percent.



Figure 7. (Discount rate: 45 percent).

In this model it is in fact rather easy to calculate the maximum discount rate for condition (22) above to hold. In salmonella level 2 the pig producer faces a reneging temptation of 1.42, which also represents the pig producers' maximum reneging temptation. With a discount rate less than or equal to 0.181 the relational contract will still be implementable:

$$\frac{1}{0.181} \cdot 0.259 = 1.42$$

In salmonella level 3 the pig producer faces a slightly smaller reneging temptation of 1.35. This requires an interest rate equal to or less than 0.192:

$$\frac{1}{0.192} \cdot 0.259 = 1.35$$

Finally, the slaughterhouse faces the lowest reneging temptation of only 0.72. That makes the relational contract implementable as long as the discount rate is equal to or below 0.357.

Thus, we can conclude that, given the assumptions of the model, relational contracting is feasible for discount rates below 0.357. The decision right should be given to the slaughterhouse which faces the lowest maximum reneging temptation.

Summary

We applied a formal theoretical model of adaptation to two empirical settings within the agri-food industry: specialized pig production and food safety in Denmark. The objective is to allocate decision rights ex ante so that actual decisions taken ex post will optimize the profit accruing to the two parties in a contractual or integrative relation.

Two applications have been presented in this paper: First an actual partnership between two pork producers in Denmark. Based on detailed budgets we develop detailed schedules for the “reneging temptations” of the two partners- These are the temptations to renege on the contract during the evolution of the partnership. Using a model developed by Baker, Gibbons and Murphy (2006) we calculate equilibria using the Folk theorem in order to determine which is the best allocation of decision rights. We find that the existing allocation of decision rights in the case we examine is efficient in the sense that it results into a second best allocation.

Using the same modelling approach we presented a second application on salmonella control related to end-feeding, that is, salmonella contamination of pork due to filled bellies of pigs fed for the last 12 hours before delivery. Based on appropriate assumptions, the parties should give the decision right (whether to end-feed or not) to the slaughterhouse in order to reach the first-best solution which, given the assumptions, is feasible

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